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The effect of transient lateral internal gravity wave propagation on the resolved atmosphere in ICON/MS-GWaM

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Internal gravity waves are commonly parametrized in both weather and climate models to capture their important impacts on the large-scale resolved flow. To reduce the model complexity and increase the performance, these parametrizations typically neglect both the horizontal wave propagation, assuming a horizontally homogeneous local flow (columnar approximation), and the time dependence of the gravity wave dynamics (steady-state approximation). However, a number of studies have shown that these assumptions do not hold in general and might lead to systematic biases in the simulated atmosphere.

The recently introduced Multi-Scale Gravity Wave Model (MS-GWaM), implemented into the ICOsahedral Non-hydrostatic model (ICON), aims to relax the above-mentioned simplifications. In particular, the model simulates gravity waves with Lagrangian ray tracing methods while being coupled to the mean flow and allowing for a transient, three-dimensional propagation. In the current implementation, the model replaces the non-orographic wave drag parametrization.

We find that the 3-dimensional propagation and refraction of gravity waves and the correspondingly modified momentum/energy transport pathways have a significant impact on the middle atmosphere. For instance, the wave refraction around the Antarctic winter jet leads to the often observed convergence near the jet edges. Moreover, the horizontal propagation introduces wave drag at latitudes around 60°S and altitudes around 40 km – a region where it is typically missing in atmospheric models. The probability density functions of wave momentum fluxes exhibit the commonly observed long tails (i.e., wave intermittency) which cannot be reproduced with steady-state parameterizations. Additionally, the intermittent wave field's horizontal distribution displays significantly altered patterns. As an important consequence, the structure of the Quasi-biennial Oscillation (QBO) is significantly improved.

Recent efforts have focused on enhancing the model's efficiency, transforming it into a modular configuration, improving its general usability, and adapting it to work with the most recent version of ICON. By implementing these modifications, we aim to increase the accessibility of MS-GWaM to the community and thus establish a robust contribution to the ICON ecosystem.